Energy
National Research Programmes 70 and 71

Project

Technical evaluation of multi-energy hub systems

Plan renewable energies in combinations

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In order to correctly plan systems for the decentralised provision of energy, it is necessary to also incorporate future technical developments alongside considerations relating to the current situation. Until now, however, there has been no generally accepted method for this process. As part of an analysis, ETH Zurich researchers have now taken a look at the future of renewable technologies and developed a method for their planning and utilisation on this basis.

Renewable energy sources such as solar and wind power are becoming ever more important. To obtain the optimum output from these sources, the interaction between power plants and storage systems needs to be planned over the long term. *Source:* DiyanaDimitrova/iStock

At a glance

- In future, renewable energies could be optimally utilised in so-called multi-energy hubs. These are decentralised systems that link various energy sources – electricity, heat, gas – together via small power plants and energy storage solutions.
- In order to plan the interplay between the different technologies, however, future technical developments as well as uncertainties relating to these forecasts also need to be taken into account in as accurate and efficient a manner as possible.
- Process engineers at ETH Zurich have now developed computer models that can map the used technologies both now and in the future. With the help of these models, multi-energy hubs can be planned in detail and simulated under operating conditions.

In addition to several large power plants, so-called multi-energy hubs could in future provide a considerable share of our energy. These are linked systems comprising small power plants and storage solutions. This allows for solar plants, wind turbines, heat pumps, batteries, heat storage devices and power-to-gas systems, among others, to be linked together and for their operations to be coordinated. The objective here is to utilise renewable energy sources as optimally as possible and thus reduce CO2 emissions. However, developing such multi-energy systems and even just planning them has been difficult until now as there has only been very simplified – and thus imprecise – methods available to this end.

There is a reason for this: "In order to plan systems correctly, appropriate account of future developments also has to be taken to the greatest degree possible", says Marco Mazzotti, a professor for process engineering at ETH Zurich. And there are many uncertainties with respect to such forecasts: how will weather conditions change and therefore also the energy yields generated by solar and wind energy plants? How will the output of the technical systems develop? In line with energy prices and demand for renewable electricity which then in turn influences the acquisition and operating costs of the systems? A planning method for multi-energy hubs needs to be able to answer all of these questions in as realistic a manner as possible. Such a method has been developed by Mazzotti together with his research team. It allows for multi-energy hubs to be modelled and simulated under operating conditions – taking account of future developments that influence the systems.

To this end, the researchers mapped such multi-energy hubs in computer models. In this sub-project, they initially focussed on the systems' technical characteristics. They created so-called thermoelectric models for all systems that could be integrated in a hub. Using such models, the behaviour of the systems, for example photovoltaic modules or a heat pump, can be mapped. The researchers also incorporated various forecast parameters, including weather data and price developments. These are required in order to simulate the operation and costs of the systems.

A higher level of detail is not always better

This process initially produced very complex and detailed models for the various energy systems. However, the ETH process engineers had to reduce this complexity once more in order to even make the elaborate calculations possible with the computer models. They ultimately used approximate values, which were, however, based on the detailed models. “We looked to find a balance between the level of detail offered by the models and the degree of uncertainty in the forecasts”, explains Mazzotti. This is because the more details that are incorporated in a model, the more precisely it maps reality. However, this also necessitates more computing power. Furthermore, the more forecast parameters there are in the model, the more pronounced the impact of the uncertainty in the forecasts over the long term – meaning that a greater degree of detail can, as the case may be, even lead to significant deviations within the service life of a system.

The researchers found the appropriate level of detail by comparing their models with experimental data from scientific publications or from commercially available systems. This allowed them to create simplified models for solar, wind and hydropower plants. On the other hand, more complex models were required in order to describe other energy systems such as power-to-gas systems and combined heat and power plants.

Convert electricity into gas and use it for heating

Power-to-gas systems, in particular, could in future become an important part of multi-energy hubs. They convert electric energy into a gas. This can be stored on a long-term basis and be used later for heating, for example. Such systems are therefore deemed to provide a promising option for balancing out seasonal fluctuations from renewable energy production.

In contrast, combined heat and power plants are usually there to obtain the maximum from conventional heating plants. They ensure that, in addition to the produced electricity, the incidentally produced waste heat is also utilised. Mazzotti’s team modelled the micro-variant of such systems within his method: gas-powered thermal power plants as a supplier of electricity and heating for individual residential buildings. In addition to natural gas, environmentally friendly biogas from waste as well as renewable raw materials can also be burned in these plants.

More than technology

In two separate sub-projects, the ETH researchers also simulated the operation and management of multi-energy hubs and investigated their economic viability both now and in the future – these aspects were also incorporated in their computer models.

According to the researchers, the resulting models for the first time provide a method that allows for the optimal design of multi-energy hubs to be planned for very different districts. It is thus possible to determine how the respective systems can be ideally integrated into existing energy infrastructure and at what level of utilisation they optimally interact.

To date, the researchers have tested their method in two case studies: one in the Engadine village of Zernez and one in the Zurich district of Altstetten. For both of these districts, they planned a multi-energy hub and analysed its impact. Result: CO2 emissions would fall considerably at both locations, with the levels in Zernez even coming in below the limit defined under Energy Strategy 2050.

In a next step, the process engineers want to apply their method to other districts. A project looking at the Hönngerberg ETH campus is already being discussed.

Produkte aus diesem Projekt

- A MILP model for the design of multi-energy systems with long-term energy storage
  Date of publication: 11.10.19
- On the optimal design of membrane-based gas separation processes
  Date of publication: 11.10.19
- Modeling for optimal operation of PEM fuel cells and electrolyzers
  Date of publication: 11.10.19
- Optimal design of multi-energy systems with seasonal storage
  Date of publication: 11.10.19

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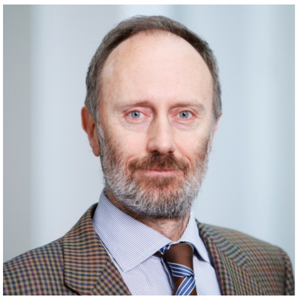
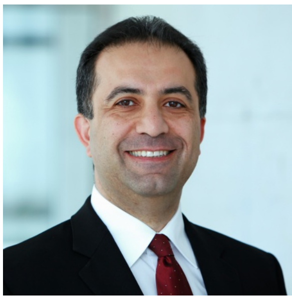


Marco Mazzotti
Project director



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All information provided on these pages corresponds to the status of knowledge as of 10.05.2019.